

DESIGNING TEACHER PROFESSIONAL DEVELOPMENT FOR MATHEMATICS TEACHING WITH VARIATION THEORY

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Abstract

In this study, we aimed at demonstrating the power of Variation Theory in exploring the local situation of Indonesian teachers and Teacher Professional Development program. The projection of Variation theory regarding the enterprise of teaching results on the need of sensitivity of students and exemplary teaching strategy that differ with teachers teaching style. Besides, It requires more opportunities for teachers to understand the critical feature of object of learning. By sequence of activity that elaborating variation theory and regards the local situation might imply the improvement of students learning.

Keywords: Variation Theory, Teacher Professional Development, Indonesia

Abstrak

Makalah ini bertujuan untuk mendemonstrasikan penggunaan *Variation Theory* dalam mengeksplorasi situasi lokal dari guru Indonesia and program peningkatan profesional guru. Proyeksi dari *Variation Theory* dalam pengajaran menunjukkan kebutuhan akan sensitifitas terhadap siswa dan perlunya contoh strategi pengajaran yang berbeda untuk guru. Selain itu, guru membutuhkan kesempatan yang lebih untuk memahami *critical feature* dari *object of learning*. Dengan aktifitas yang mengelaborasi variation theory dan memperhatikan situasi lokal dapat menghasilkan peningkatan pembelajaran siswa.

Kata Kunci: *Variation Theory*, Peningkatan Profesional Guru, Indonesia

Students' achievement on international comparison study in Trends in International Mathematics and Science Study (TIMSS) and Teachers' competences necessary for mathematics teaching in Teacher Education and Development Study in Mathematics (TEDS-M) could be considered as benchmark for mathematics education reform, school and teaching effectiveness. The study of Schmidt, Houang & Cogan (2011) suggested that there was the strong connection between the knowledge of potential future teachers and students' achievement performed in TEDS-M and TIMSS respectively. These could be interpreted that the quality of teachers might influence the students' performance in Mathematics. Reflecting the TIMSS result data, Indonesia as a developing country in Southeast Asia had low score of mathematics achievement in TIMSS as well as in PISA. These heighten the sense of urgency of improving professional teaching. Many initiatives on Teacher Professional Development (TPD) program were made to support teacher to have reformation in mathematics achievement and increase students mathematics understanding in Indonesia. However, as in many cases, the current practice of Teacher Professional Development in Indonesia is in the form of top down TPD with predetermined subject, strategies, instructor and time table and isolated from the classroom reality

(Widodo & Riandi, 2013), having prescriptive information dissemination and new developments in very short training periods in which teachers posit as passive receiver rather than within active and interactive teacher learning collaboration.

There was also finding in Ekawati & Lin (2013) that teachers moved back to teach algorithm after the contextual situation introduces when they learn realistic mathematics approach. Looking at the profile of Indonesian teacher, the study of Ekawati, Lin & Yang (in press) show the need of Opportunity to learn for teachers in the factor of 'knowing students' and 'teaching strategy'. Furthermore, Indonesia is considered as a country with dispersed geography and the biggest archipelago in the world with variety of culture embedded and huge number of teachers made the Government face the challenge on the developing such effective program for teachers. As an example, the study of Widodo et.al (2006) with science teachers in three district in West Java showed that around 50% of teachers applied what they have learnt in TPD, with only 27% of them applying it for more than one year.

From these phenomenon, we can see that one challenges for TPD in Indonesia is that teacher lack opportunity to discern the critical feature that allow them to be more aware on the approach to work such as designing teaching task that reveal the local students situation. In order to face the challenge, the learning study with variation theory (Marton & Pang 2006; Lo 2012) can be used as empirical theoretical basis. Variation theory of learning serves as a guiding principles for the Teacher Professional Development designer to explore the picture of mathematics teaching and learning in local situation and suggesting the potential design for the teacher. Moreover, for teacher, it can also be used as guidance for their pedagogical learning such as lesson analysis and designing lesson.

In this paper, we demonstrate the power of variation theory in projecting Indonesian teacher situation, mathematics teaching and students' learning of mathematics and its challenges, and subsequently propose the TPD program to improve student learning in a setting with variation theory.

Variation Theory

Variation theory is a theory of learning and experience that explains how a learner might come to see, understand, or experience a given phenomenon in a certain way described by Marton and Booth (1997), Bowden and Marton (1998), Runesson (2005) and Lo (2012). It postulates that the learning is always directed at "something" (a phenomena, an object, or certain aspect of the reality) and is related to how people make sense of it, thus developing a certain skill, value, or capability in dealing with it- this is referred to as an 'object of learning' (Ling, Chik & Pang, 2006). To be more specific, object of learning refers to the knowledge of a certain subject that we want student to learn (it usually aimed at a short-term educational goal) and the general aspect which refers to the capability or attitude that can be developed through the learning of the content in question (this aspect is usually aimed at a long-term educational goal). In terms of mathematics teaching approach, variation theory account for students' centre (Lo, 2012) and active learning.

There were three kinds object of learning that can be distinguished such as the lived object of learning, the intended object of learning and the enacted object of learning (Marton, Runesson & Tsui, 2004). The lived object denoted what is actually learned (Runesson & Marton, 2002), in which what is learned from the learner point of view. Furthermore, the intended object of learning regarded the competences that teachers want the learners to develop. The enacted object of learning is the outcome of teachers' classroom practice and provides students with the space to learning something, making the learning of something 'possible' (Lo, 2012). Every object of learning has critical feature and it is important to identify the critical feature of object of learning. The critical fetures of object of learning that is learned in one situation might not be in another and depend on the local situation.

Determining the critical feature lies on two important reasons such as to facilitate teachers' understanding of the object of learning and to help teachers deal with students' individual differences. These could be considered in the Teachers Professional Development Program. Furthermore, the critical features were also help teacher to deal with students' individual differences in learning. In order to tackle the problem of students diversity, teachers need to identify and help students to discern critical features of the object of learning. Some teachers might have difficulties in discern the critical features so that they were not able to highlight it in the teaching due to the lack of awareness. Therefore, it needs a space of learning opportunities for teachers to find the critical features of object of learning such as by sharing past experience of the topic among teachers, interviewing students, literature review, carefully diagnostic pre and post test to students, analyzing students response and observing lesson.

In the Teachers Professional Development program, teachers are given learning environment where teacher will experience the material presented and they will notice, recognize the importance of and make meaning from certain critical features of the concept to be learned (reffered to as object of learning in variation theory). Noticing the critical feature of object of learning related to several key process and concept that underlie learning including *awareness*, *discernment* and *simultaneity* (Bussey et.al. 2012). In experiencing the phenomenon, learner might unable to aware of all aspect of phenomenon. The second key process and concept that underlie learning is discernment. It refers to the ability to hold an aspect of phenomenon in focal awareness and contrast it with its environment in order to make meaning of the object. In order to developing understanding of a concept, it is not enough to aware the single feature in discrete moment in time. Teacher must be simultaneously aware of multiple critical features of the concept. The relationship among those three key concept and the aspect of the phenomena are discerned ad simultaneously present in the individual focal awareness define the individual way of experiencing the phenomena (Martoon & Booth, 1997).

The Conceptual Framework of Designing TPD With Variation Theory

The learning study approach is premised on variation theory (Pang & Ling, 2011). There are three conceptual framework of learning study such as focusing the object of learning, adopting the view that knowing is a way of seeing and building on three types of Variation. The first type of

variation (V1) considered the variation the students' way of understanding the object of learning so that the students' difference could be recognised by teachers. By that, we can encourage teacher to explore to what extent the teaching will be. The second variation (V2) regarded variation in teachers' understanding and ways of dealing with object of learning. It provides opportunities to teacher to discuss different ideas about teaching a particular students group and particular topic. Furthermore, the third type of variation (V3) deal with using variation as a guiding principle of pedagogical design with the knowledge that teacher have in V1 and V2. The three type of variation could be used as basis framework to design the TPD program.

Exploring the local situation need to be done by designer of TPD to Variation theory can project analyse current situation and regard as the consideration point before design the TPD program. Variation theory regards teacher to draw out and work with students' existing understanding, teacher are teaching subject matter in depth and emphasis on the selection of example to provide opportunity for students to discern the critical feature of object of learning, and teaching strategy that are student centre which focus on pattern of variation such as teaching by contrast. The figure 1 below illustrated the dynamical role of variation theory as the basis for analysis and explore the current Indonesia's phenomena by projecting the factor in the variation theory. In addition, within the variation theory, TPD's developer can propose the program with regard to the local current situation.

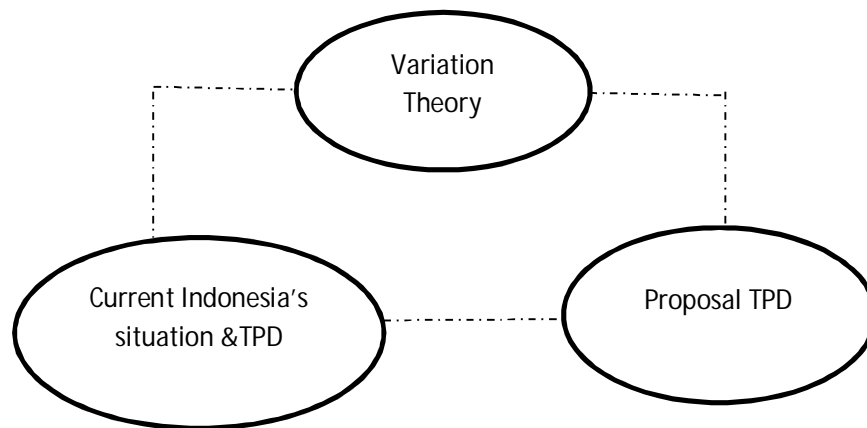


Figure 1. Dynamical Role of Variation Theory

Analysing Current Indonesia's Situation and Teacher Professional Development With Variation Theory

Indonesia is a country with 17508 islands include 5 major islands and 6000 inhabitant islands with 240 million of population and varies ethnic groups. It shows the heterogeneous of Indonesia which might also results on the varies of teachers. The big number of teachers, the geography of Indonesia and limited funding create a challenge for conducting nationwide and sustainable TPD for all teachers. Furthermore, according to World Bank (2010), the education attainment of many Indonesian teachers is still lower than what is required by law (The teacher law passed in 2005

required that all teachers have a four-year degree). Commonly, primary teachers in Indonesia are classical teachers in which they teach across subject include mathematics and therefore the education background were varied. There were teachers with non-mathematics background and non primary education college such as teachers with Indonesian language major, Engineer major and social politics major.

Variation theory could project the current situation in which compatibles with the three learning principled described by Donovan et.al (1999) and give rise on implication for teaching and teacher preparation. One of it is that teachers must draw out and work with the existing understanding that their students bring with them. In 2013, we explored primary teachers' Mathematics Content Knowledge (MCK) and Mathematics Pedagogical Content Knowledge (MPCK) on ratio and proportion with 271 participants from four districts in East Java Indonesia to get more insight of Indonesian primary teachers' profile. Result on MCK showed that teachers perform best in representing the product of proportional reasoning by doing calculation and they need more understanding of the connection of ratio and proportion concept with figural representation and number structure in situation (Ekawati et.al, submitted manuscript). In addition, for MPCK, most teachers needed more opportunity for sensitivity of students in terms of students strategy and misconception on mathematics content. 29.52% of teachers' participants were also needed more understanding on teaching strategy of ratio and proportion. The sensitivity of students consist of students understanding of specific and related topics and understanding students' misconception of specific topic. The variation theory also regarded teachers must teach subject matter in depth and providing many examples in which the same concept is at work to give a firm foundation of factual knowledge. Relies on this component, based on field data collection on teaching, Indonesian teachers gave many example to students. However, the example given to students were in similar form in which students lack opportunities to discern the critical features of object of learning from the examples shared. In addition, the teaching of metacognitive skills should be integrated into curriculum in a variety of subject area. Variation Theory point to teaching strategies that are students centre and focus on pattern of variation such as teaching by contrast and separation. The fact in Indonesia based on TIMSS video study and field data collection shows that teacher intended to apply direct instruction and less opportunity for students to explore their view & understanding of the object of learning.

In terms of teacher learning, variation theory suggested a need to facilitate teacher understanding of the object of learning within active learning. The Teacher Professional Development in Indonesia have common strategy chosen by Government such as Training of Trainers model in which teachers who successfully participated in this training are supposed to train other teacher. Moreover, the integration of technology in Teacher Professional Development were also considered such as Online Teacher Professional Development (Sari, 2012) and top down pattern (Widodo & riandi, 2012) in which facilitator gave talk and teachers as listener. Recent interview with 5 primary teachers in Indonesia regarding their experience in participating in Teacher Professional Development

showed that teachers were more appreciate the workshop form in which they were given exemplary teaching rather than became listeners in a seminar based on their experience.

Variation theory regards two aspect object of learning such as specific aspect and general aspect. In designing lesson, Indonesian teachers were only consider specific aspect of learning (subject matter/knowledge/skills that we wish students to learn). It is usually appeared in curriculum. Teachers gave less opportunity to students to explore the general aspect (capabilities that can be developed through the learning of specific aspect which is long term goal).

Proposal of Teacher Professional Development With Variation Theory

In this part, we develop a proposal of Teacher Professional Development for mathematics teaching. Since the core of the TPD in this proposal is about mathematics teaching, it is necessary to invite teacher to aware the feature of teaching mathematics. Teaching principles derived from Variation Theory are compatible with many principle of teaching on which the educational community has reaches a consensus (Lo, 2012) such as the need of draw out and work with existing understanding that student bring and teacher must teach mathematics content in depth with providing many examples. To make real changes in classroom mathematics teaching and start the discussion regarding the teaching principle, it is useful to take the lesson as point as departure (Nuthal, 2004; Stigler & Hibert, 1999). Therefore the proposal of first activity and its goal are described in Table 1.

Table 1. the Proposal of First Activity and Its Goal

Goal	Proposal of Activity
1. To develop teachers' awareness of the feature of teaching and explore the local teachers' teaching	<p>1. Teachers share their experience of mathematics teaching on specific topics with regard to the teaching principle based on variation theory on specific mathematics topic.</p> <p><u>Example:</u> Based on the teaching principles (i.e. the need to draw out and work with existing understanding that student bring and teacher must teach mathematics content in depth with providing many examples), teachers share their experience on teaching ratio and proportion. For instance:</p> <p>(a) Teacher may share the existing understanding that students have such as fraction and equivalence fraction.</p> <p>(b) Teacher discuss their given examples problem related to ratio and proportion (whether it is based on textbook or not)</p>

In teaching mathematics, teachers have the responsibility to encourage students' learning. Jawroski (1994) offers a teaching triad which synthesize three elements that are involved in creating opportunities for students to learn mathematics such as the management of learning, sensitivity of students and the mathematical challenge. These elements are considered as the feature of teaching. In addition, within the teachers' professional learning community, those three elements become part of the teaching triad for mathematics teacher educators. The sensitivity of students is an important factor in teaching. Result on assessment to Indonesian primary teachers' Mathematics Pedagogical Content

Knowledge in 2013 showed that 70.48% teachers needed more sensitivity on students (Ekawati et.al submitted manuscript). To be more specific, it considered understanding students' misconception and different students' strategies in solving ratio and proportion problem. In addition, giving feedback to students' misconception and analyzing students solution became the most challenging for all teachers. Teachers are lack of awareness about these factors due to in their practice, they were not giving opportunity to students to deal with misconception and different students strategies. There was a tendency that teachers only apply direct instruction and give less opportunity for students to explore their understanding of the object of learning (TIMSS video study and field data collection). Interview with Indonesian teachers showed that they tend to use National Textbook (BSE) as basis for their teaching and gave task from the textbook. Take teacher background and regard the situation, teachers need experience to aware the sensitivity of students. Therefore, the second activity is described in Table 2.

Table 2. the Second Activity and Its Goal

Goal	Proposal of Activity
2.1 To develop teachers' awareness and understanding of the sensitivity of students	<p>2.1 Teacher analyze the critical feature of exemplary teaching video with students misconception in it.</p> <p><u>Example :</u></p> <ul style="list-style-type: none"> • In a teaching scene, a student solve enlargement figure problem (i.e enlarge rectangle) by using addition. Teachers may analyse and discuss this students' misconception. • In a teaching scene, a teacher stated that students will learn ratio and proportion with sum. Afterward, she posed a problem such as : "The ratio of Ega's money to Yoga's money is 3 : 7. Yoga's money is Rp. 14000,-. How much Ega's money?." A student solves this problem by $\frac{3+7}{7} \times 14000 = 20000$ and so the total money is $20000 + 14000 = 34000$. By this scene, teachers can analyse the underline reason why student use this strategy.
2.2 To open teachers' perspective on different mathematics teaching approach.	<p>2.2 Teachers analyze the critical feature of exemplary teaching module with active constructive and inquiry approach compare to their own teaching using textbook as basis.</p> <p><u>Example:</u></p> <p>In the 7th grade of Indonesia Electronic School Textbook (Wagiyo et.al, 2008) , there is an example of problem with solution about finding the height of a house in the picture with given the real length and weight of house.</p> <hr/> <p>"An architect design a picture of a house with length 15 m and 12 m. If the length in the picture is 10 cm, what is the height in the picture?"</p> <p>Solution:</p> $\frac{t}{12} = \frac{10}{15} \leftrightarrow 15 t = 12.10 \leftrightarrow t = \frac{12 \times 10}{15} \leftrightarrow t = 8$ <p>So the height in picture is 8 cm"</p> <hr/> <p>Exemplary teaching module (Hart, 1984)</p> <p>The content of teaching session was designed to gave sense of "enlargement" and not only provide a progression to the correct solution. The same unit is used and the notes which the outline the teaching as follows:</p> <p>(1) Children measure and draw segments suggested by answers in order to see the</p>

outcome of using incorrect addition strategy

- (2) Multiplication is emphasized by teacher asking for enlargement of figures by a large integer scale factor. The dimensions of the original figure being small whole numbers and $1\frac{1}{2}$.
- (3) Enlargement by scale factors of $1\frac{1}{2}$ and $2\frac{1}{2}$, the original and enlargement being drawn for the pupils with dimensions of the original being integers and halves. The teacher to accept 'take it once and add a half of it' for $1\frac{1}{2}$ times an amount but to ask the child if there is another method. It was expected that the children would have trouble with $2\frac{1}{2} \times 4\frac{1}{2}$ type question.
- (4) Examples where the scale factor is not given but a clue is given such as "for every 3 cm in this diagram, there is 5 cm in the large diagram"
- (5) Discussion and revision of multiplication of fractions. The rule for multiplication being built by recourse to the rule for the area of a rectangle and the use of the word 'of'
- (6) Review improper fractions and cancelling, taking as the 'preferred' method the leaving of products of numerators and denominators until the end i.e. $\frac{a}{b} \times \frac{c}{d} = \frac{ac}{bd}$ and then cancelling.
- (7) Using multiplication of fractions on diminution (one-fifth of, one-third of). Child to draw resultant diagrams where original diagram has dimensions of integer and halves.
- (8) Return to previous items and use multiplication of fraction for solution.
- (9) Provide method for finding the scale factor having been asked by children after they have tried items of the sort '3 cm becomes 5 cm'. Emphasis placed on verbalizing problem as '3 times something gives 5'. Probably need x for 'something'
- (10) Review of solution of equations such as $3x = 5$ in order to find scale factor which can then be applied
- (11) Question children on whether scale factor should be more or less than one and so whether one expects an enlargement or a diminution.

Teachers analyze the critical feature of teaching sequence in teaching module in which students are given experience to understand the similar figures and the used of multiplication in the enlargement problem. These might be different with teachers teaching approach with textbook as basis in which focus on cross multiplication procedure as progression to the correct solution.

After the process of analyzing the critical feature on sensitivity of students and opening perspective on different mathematics teaching approach, there might be pedagogical problem that they encounter. Therefore, teachers' need to share their pedagogical problem regarding the appropriateness of variety mathematics teaching approach with the local situation which appear in the third activity (see in Table 3).

Table 3. the Third Activity and Its Goal

Goal	Proposal of Activity
3.1 To give opportunity to teachers to share their pedagogical problem.	<p>3.1 Teacher communicates their pedagogical problem on specific topic of teaching approach.</p> <p><u>Example:</u> Teacher may have a pedagogical problem such as there is still student who not able to do multiplication to solve enlargement problem.</p>

The fourth activity design to develop teachers' concrete feeling about teaching by having sensitivity of students and after analyzing different teaching approach (see in Table 4).

Table 4. the Fourth Activity and Its Goal

Goal	Proposal of Activity
4.1 To give opportunity to teachers to imitate or modify the teaching approach in the module.	4.1 Teacher design lesson with regard to their local situation and condition by adapting/modifying the exemplary teaching approach. <u>Example:</u> Teacher may modify the scale factor used such as using integer scale factor first and then fractional scale factor since some students might have difficulties in multiplication of fraction.
4.2 To develop teachers' sensitivity of teaching.	4.2 Implementing the lesson design

Variation theory can also be used as pedagogical principle to analyse lesson and provide feedback for teachers to improve teaching and achieve better student learning. After teachers implement the lesson design, teachers can find out whether students have learnt the intended object of learning or not. The critical features of object of learning within the lesson are identified. In addition, teachers need to explore how students discern the critical features in the lesson whether students discern multiple critical features or only individual critical feature achieved (see in Table 5).

Table 5. the Last Activity and Its Goal

Goal	Proposal of Activity						
5. To give opportunity to teachers to analyse lesson with variation theory and revised the lesson if it necessary.	<p>5. Teachers analyze teachers' authentic teaching by exploring the critical feature of object of learning within the lesson and the students' discernment of the critical features. Teachers might revise their design lesson.</p> <p><u>Example :</u> The intended object of learning is “the role of multiplication factor scale in enlargement figure”. The critical features (CF) were identified.</p> <p>CF1: The enlargement by integer scale factor.</p> <p>CF2: The diminution by non-integer multiple scale factor.</p> <p>CF3: The idea of multiplication in the enlargement is emphasized with verbal statement clue such as “for every x cm in diagram, there is y cm in the large diagram”</p> <p>The students’ discernment of critical features might be single or multiple depend on the result of authentic teaching. There is probably a lesson that teacher focus on one or two critical features only. The enactment of the pattern of variation might also be different, one example is given as the following pattern of variation:</p> <table><tr><th>Invariant</th><th>Varied</th><th>Discernment</th></tr><tr><td>Integer and non-integer multiple</td><td>Enlargement, diminution or</td><td>When the factor scale multiplier is</td></tr></table>	Invariant	Varied	Discernment	Integer and non-integer multiple	Enlargement, diminution or	When the factor scale multiplier is
Invariant	Varied	Discernment					
Integer and non-integer multiple	Enlargement, diminution or	When the factor scale multiplier is					

	scale factor	exactly same	integer, the figure will be enlarged or same.
			When the factor scale multiplier is non-integer, the figure will be diminut.
From the authentic teaching, teacher can analyze whether aims of the lesson achieved or not. For example: teacher may find students still use additive strategy to find the enlarged figure or segment size.			

CONCLUSION AND SUGGESTION

The dual used of variation theory were the main result of this study. The first role of variation theory is used to project Indonesia local situation of teachers, mathematics teaching, students learning and its challenges. Based on the result of analyzing local situation, subsequently, variation theory can be used as basis to develop a proposal for designing Teacher Professional Development Program. With regard to the profile of Indonesian teachers, we proposed learning activity in which Indonesian teachers develop their awareness of the feature of teaching mathematics. It regards the sensitivity of students and the different mathematics teaching approach by considering the National textbook.

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